Check List the journal of biodiversity data

LISTS OF SPECIES

Check List 11(6): 1798, 27 November 2015 doi: http://dx.doi.org/10.15560/11.6.1798
ISSN 1809-127X

Ferns and lycophytes from Jaú, São Paulo, Brazil

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Abstract: This work presented the inventory of ferns and lycophytes of Jaú, São Paulo state. Sixty-eight species of ferns and one of lycophyte were recorded, distributed in 16 families and 32 genera. The richest families were Pteridaceae and Thelypteridaceae with 15 species each, Polypodiaceae (7spp.), Blechnaceae and Dryopteridaceae (5 spp. each). The most common guild of life form was terrestrial herbs with 57 species, followed by epiphytes (6 spp.), arborescent, aquatic and lithophytes (2 spp. each) and hemiepiphytes and scandents with one species each. The analysis of the geographical distribution showed that 46% of the species (32 spp.) occur in the Neotropics, 20 species occurs in Southern America, eight are endemic of Brazil, five pantropical and four are exotic. This study can further collaborate in the protection and preservation of the few remnants which represent probably the last areas where some species of these groups of plants occurring in the municipality.

Key words: semideciduous forest; swamp forest; Atlantic Forest; conservation; inventory

INTRODUCTION

Ferns and lycophytes represent a group of vascular plants that do not produce flowers or fruits. They have an interesting alternation of generations life cycle. That is, the sporophyte generation produces the spores and lives for a long time while the gametophyte generation, that reproduces sexually, is smaller in size and has a short life span. These plants were historically associated in a paraphyletic group called Pteridophyta mainly due the presence of spores (Pryer et al. 2004; Schuettpelz and Pryer 2008; Smith et al. 2006). Therefore, recent phylogenetic studies suggested the segregation of this group in two evolutionary lines: ferns (*sensu* Pryer et al. 2004) and lycophytes, both monophyletic (Smith et al. 2006, 2008).

These groups are a conspicuous component of tropical forests and they represent about 10% of the vascular flora (Gentry 1990). For the Neotropics, Tryon and Tryon (1982) suggested the occurrence of approximately 3,250 species and the tropical forest in mountainous sites have been considered the richest area (Tryon 1986; Moran 2008). In Brazil it is estimated the occurrence of 1,253 species and for the São Paulo state it was proposed 618 taxa (Prado and Sylvestre 2015). The Atlantic Rain Forest (eastern portion of the state) and the mountainous areas in interior of state have been presented greatest diversity (Prado and Hirai 2011). Moreover, according to Prado (1998), a significant percentage of species can be found in the remnants of semideciduous forests and Cerrado in the interior of the São Paulo state.

However, few studies have been conducted in the interior of São Paulo, among them: Colli et al. (2004; 2007), Nóbrega and Prado (2008), Salino (1996), Salino and Joly (2001) and Windisch (1992). In the Municipality of Jaú, flora studies are scarce, it can be mentioned just Nicolini-Gabriel and Pagano (1993) which has no mention about ferns and lycophytes. Thus, studies in the forests remnants of the city are extremely important because it is left about 1.5% of its original vegetation (Souza and Veniziani 2012).

In this context, the aim of this study was to inventory the flora of ferns and lycophytes in the Municipality of Jaú, besides provide data about the geographical distribution and guilds of life forms of the species found.

MATERIAL AND METHODS

Study area

This study was conducted in the municipality of Jaú, located at the central portion of the São Paulo State. Its mean temperature is 20°C with average annual rainfall of 1,428 mm and its climate is classified as proposed by Köppen (1948) as "Awa" (Nicolini-Gabriel and Pagano 1993). The terrain is slightly hilly and slightly wavy with mean elevation of 564 m (Souza and Veniziani 2012). Current data suggests that in Jaú the remnants of original vegetation, which amount about 1.5% of its area (Souza and Veniziani 2012), total 1,031 ha. However, according SIFESP (2009) 528 ha the

vegetation are represented by *capoeiras* (disturbed small fragments) and approximately 500 ha of the vegetation is constituted by forests or floodplain vegetation. For this study, two areas were selected which together covers about 200 ha (Figure 1). The first area inventoried was the RPPN Amadeu Botelho which comprises 180 ha being one of the largest remaining of natural vegetation in the municipality. The area is predominantly composed of semideciduous forest with a small spot of riparian vegetation (Figure 2). The second study area comprises a remnant of about 20 ha which protects the source of the Santo Antônio stream. Its lowest points have upwelling of groundwater where the vegetation type is swamp forest while the highest points are semideciduous forest (Figure 3). It should be emphasized that these two remaining were chosen because they are the best preserved areas in the town and they represent together the flora of ferns and lycophytes from Jaú.

Collection, taxonomic treatment and ecological aspects

Samples were collected over six years (2008–2014), with regular visits (two per semester) in the two study areas. The collection and the preparation of specimens for the herbarium followed the techniques proposed by Windisch (1992). The herbarium specimens were deposited in the Herbarium of the Sagrado Coração University (BAUR) in the municipality of Bauru, São Paulo, Brazil. The adopted classification was Christenhusz et al. (2011) and Christenhusz and Schneider (2011). Names of ferns and Lycopodiaceae were updated using Rothfels et al. (2012) who adopted the proposal of Haines (2003). Data of the geographical distribution of the species were obtained from specialized literature. The guilds of life forms were treated as suggested by Paciencia (2008).

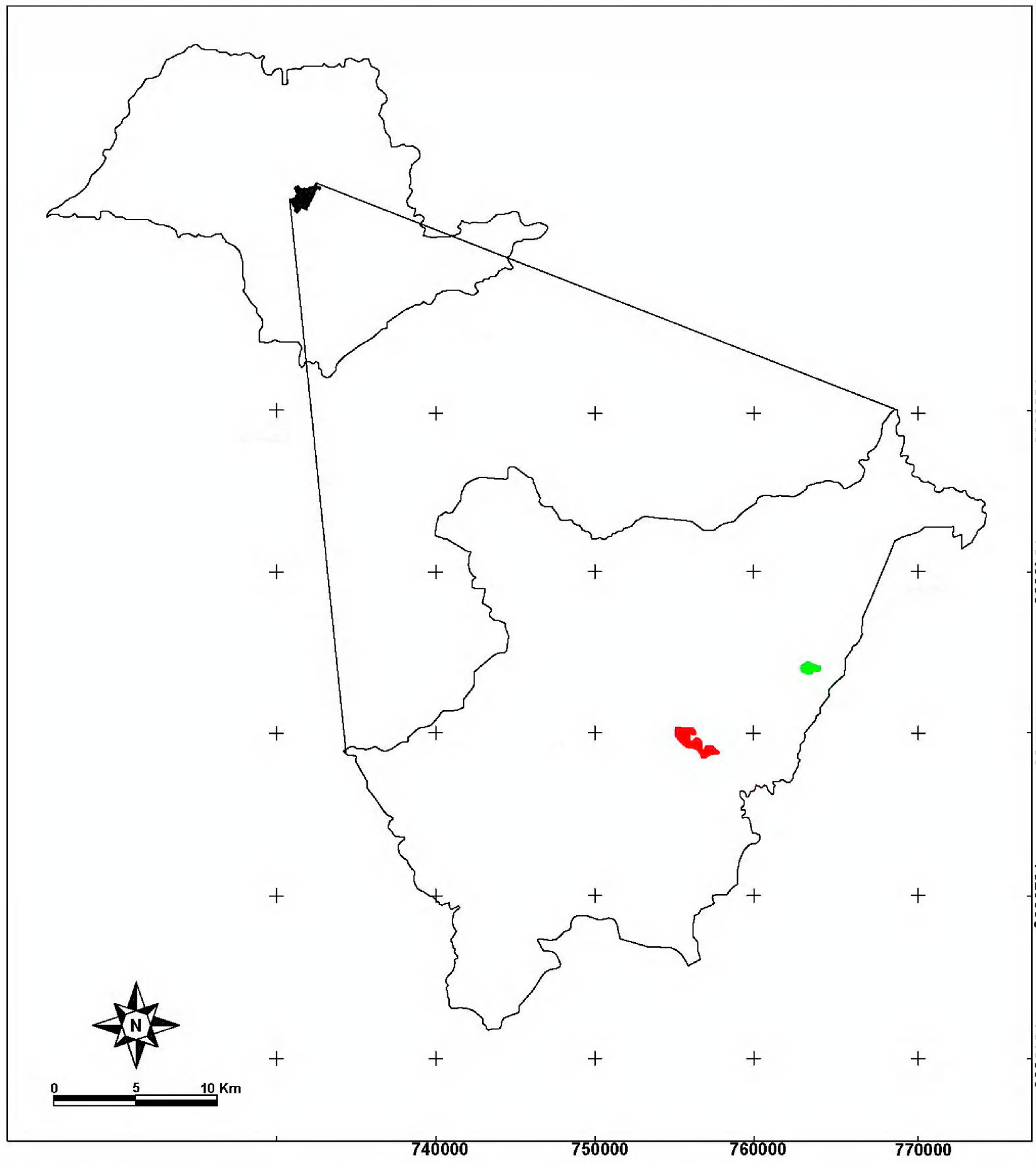

Figure 1. Location of the two forests remaining studied in Jaú, São Paulo, Brazil. Red – RPPN Amadeu Botelho; Green – Source of the Santo Antônio Stream.

Figure 2A–B: Views of the vegetation in RPPN Amadeu Botelho, Jaú, São Paulo, Brazil.

Figure 3. A–B: Forest interior surrounding the source of the Santo Antônio stream, Jaú, São Paulo, Brazil.

RESULTS

In this study, 70 species of ferns and lycophytes were found; 69 are ferns and one species is lycophyte (Figures 4–6). The most species-rich families were Pteridaceae and Thelypteridaceae with 15 species each, followed by Polypodiaceae (7 spp.); together these three families comprise approximately 53.6% of the fern richness observed for overall the municipality. *Thelypteris* was the richest genus with 14 species (20.3%) and *Adiantum, Blechnum*, and *Pteris* coming next with four species (5.8% each). All other genera presented among one to three species. Additionally, 26 species were found in the RPPN Amadeu Botelho and 55 in the forest fragment surrounding the source of the Santo Antônio stream (Table 1), with only 10 species shared between them.

Considering the two major groups inventoried, terrestrial herbs species were dominant guild of life form with 81.4% (57 spp.), followed by epiphytic species (5 spp.; about 7%), arborescent, aquatic and lithophytes (2 spp. each; less than 3%), scandents and hemiepiphytes with one species each. Regarding the geographical distribution, 45.7% of the recorded species (32 spp.) show Neotropical distribution, whereas 30% (21 spp.) occur in the South America, 11.4% (8 spp.) are endemic of Brazil, 7.1% (5 spp.) present pantropical distribution and, finally 5.7% (4 spp.) are exotics (Table 1).

DISCUSSION

The number of species found shows that Jaú provides a good representation of ferns and lycophytes of flora in the state of São Paulo (12.2%).

Comparing the two studied areas in the municipality, we noted they harbour different floristic composition and unequal number of species. Although the RPPN comprises a much larger area than locality of Santo Antônio (180 vs. 20 ha), it also presents the lowest diversity (26 vs. 55 spp.). One possible explanation for this surprising discrepancy may be rooted on the dry environment experienced by the first area, once its forest has no water source inside it. On the other hand, in the forest remnant, at the source of the Santo Antonio stream, upwelling of groundwater keeps the soil perpetually wet. Thus, keeping in mind that several authors have already demonstrated the dependent relation between the reproduction of ferns and the water

Figure 4. Some species from the studied areas (Jaú, São Paulo, Brazil). **A**: *Adiantopsis chlorophylla*; **B** and **C**: *Asplenium otites*; **D**, **E** and **F**: *Cyathea delgadii*.

Figure 5. Some species from the studied areas (Jaú, São Paulo, Brazil). **A**: *Doryopteris concolor*; **B**: *Doryopterys lomariacea*; **C**: *Hemionitis tomentosa*; **D**: *Macrothelypteris torresiana*; **E** and **F** - *Microgramma lindbergii*.

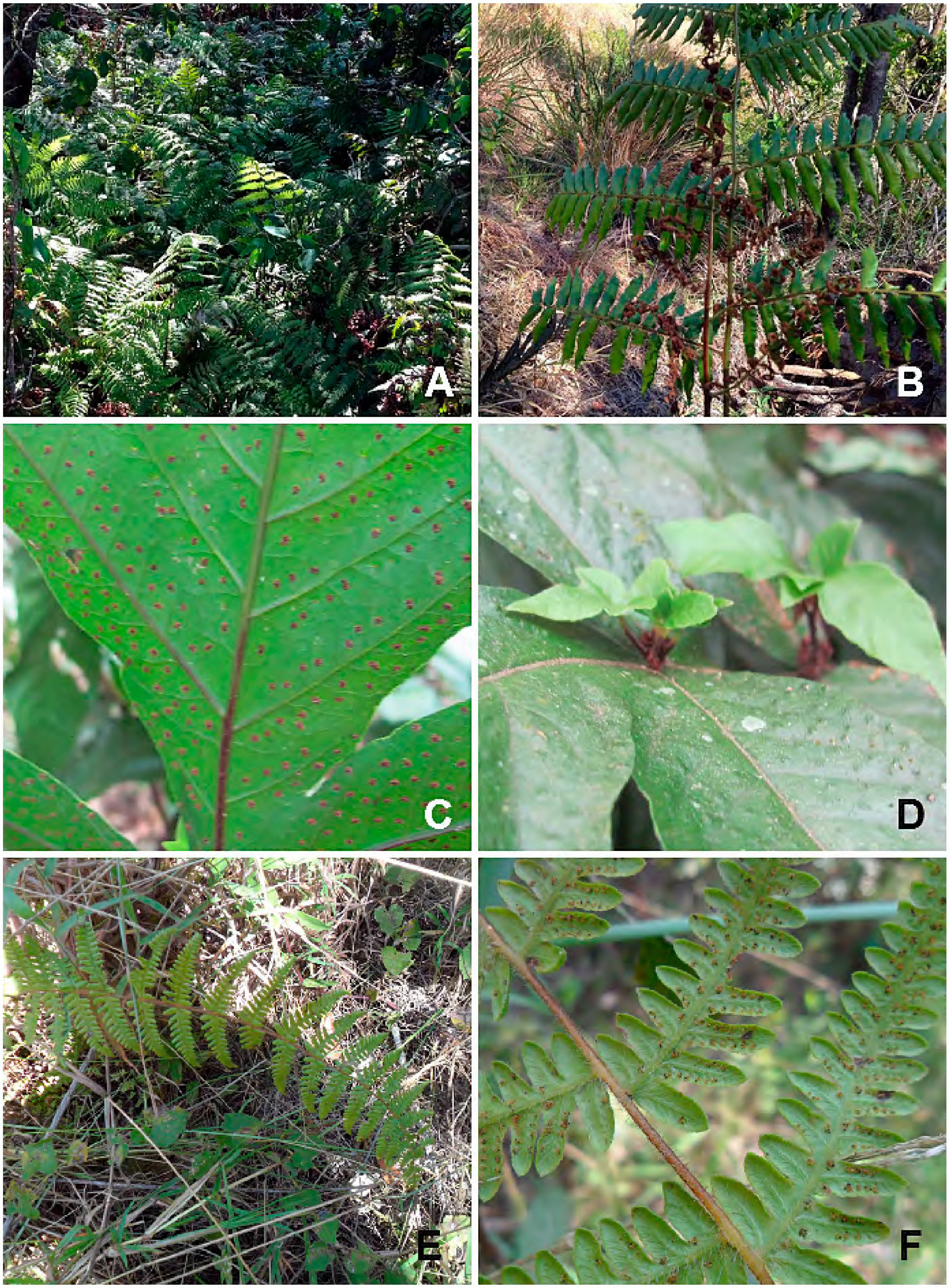

Figure 6. Some species from the studied areas (Jaú, São Paulo, Brazil). **A** and **B**: *Polybotrya goyazensis*; **C** and **D**: *Tectaria incisa*; **E** and **F**: *Thelypteris rivularioides*.

Table 1. Ferns and lycophytes from Jaú, São Paulo, Brazil. Areas – AB: Ecological Reserve Amadeu Botelho; ST: Forest Fragment surrounding the source of the Santo Antônio stream. Guilds of life forms – TR: Terrestrial herbs; EP: Epiphytes; AR: Arborescent; AQ: Aquatics; LT: Lithophytes; HP: Hemiepiphytes; SC: Scandents. Geographical distribution - NE: Neotropical; SA: Southern America; BR: Brazil; PA: Pantropical; EX: Exotic. Voucher – Collected by F.F.F. Mazziero.

Taxa	Area	Life form*	Geographical distribution	Voucher number
LYCOPHYTA				
Lycopodiaceae				
Palhinhaea cernua (L.) Franco & Vasc.	ST	TH	PA	271
FERNS				
Anemiaceae				
Anemia phyllitidis (L.) Sw.	AB/ST	TH	NE	46, 269
A. villosa Humb. & Bonpl. ex Willd.	ST	TH	SA	268
Aspleniaceae				
Asplenium abscissum Willd.	ST	TH	NE	233, 246
A. bradei Rosenst.	ST	TH	BR	244, 232, 245, 243, 234
A. brasiliense Sw.	AB	TH	SA	249, 250
A. otites Link	AB	TH	NE	10, 240, 241
Athyriaceae				
Deparia petersenii (Kunze) M.Kato	ST	TH	EX	272
Diplazium asplenioides (Kunze) C.Presl	AB	TH	NE	1257
D. cristatum (Desr.) Alston	AB	TH	NE	53, 296
D. lindbergii (Mett.) Christ	ST	TH	NE	290
Blechnaceae				
Blechnum brasiliense Desv.	ST	TH	NE	211
B. cordatum (Desv.) Hieron.	ST	TH	SA	267
B. occidentale L.	AB	TH	NE	265, 267
B. polypodioides Raddi	ST	TH	NE	416
Salpichlaena volubilis (Kaulf.) J.Sm.	ST	SC	NE	266
Cyatheaceae				
Cyathea atrovirens (Langsd. & Fisch.) Domin	ST	AR	SA	262, 338
C. delgadii Sternb.	ST	AR	NE	261
Dennstaedtiaceae				
Dennstaedtia globulifera (Poir.) Hieron.	AB	TH	NE	173, 231
D. obtusifolia (Poir.) Hieron.	ST	TH	SA	285
Dryopteridaceae				
Ctenitis distans (Brack.) Ching	ST	TH	BR	291, 339
C. falciculata (Raddi) Ching	ST	TH	SA	337
C. submarginalis (Langsd. & Fisch.) Ching	AB	TH	NE	48
Lastreopsis effusa (Sw.) Tindale	AB	TH	NE	258
Polybotrya goyazensis Brade	ST	HP	BR	270
Equisetaceae				
Equisetum giganteum L.	ST	TH	NE	282
Gleicheniaceae				
Dicranopteris flexuosa (Schrad.) Underw.	ST	TH	NE	260
Sticherus bifidus (Willd.) Ching	ST	TH	NE	259
Osmundaceae				
Osmunda regalis L.	ST	TH	PA	273
Osmundastrum cinnamomeum (L.) C.Presl	ST	TH	PA	333
Polypodiaceae				
Campyloneuron nitidum (Kaulf.) C.Presl	ST	TH	SA	288, 263
Microgramma lindbergii (Mett.) de la Sota	ST	EP	SA	414
Pleopeltis pleopeltifolia (Raddi) Alston	AB/ST	EP	BR	43
P. minima (Bory) J.Prado & R.Y.Hirai	AB/ST	EP	SA	44
Serpocaulon catharinae (Langsd. & Fisch.) A.R.Sm.	ST	EP	BR	294, 415
S. fraxinifolium (Jacq.) A.R.Sm.	ST	EP	NE	289
S. vacillans (Link) A.R.Sm.	ST	TH	NE	265, 199
Pteridaceae				
Adiantopsis chlorophylla (Sw.) Fée	ST	TH	SA	148, 331
A. radiata (L.) Fée	ST	TH	NE	274
Adiantum abscissum Schrad.	AB	TH	BR	21
A. lorentzii Hieron.	AB	TH	SA	59
A. platyphyllum Sw.	AB	TH	SA	229, 230

Continued

Table 1. *Continued.*

Taxa	Area	Life form*	Geographical distribution	Voucher number
A. tetraphyllum Willd.	AB/ST	TH	BR	35, 413, 251, 253
Doryopteris concolor (Langsd. & Fisch.) Kuhn	AB/ST	TH	PA	41
D. lomariacea Klotzsch	ST	TH	SA	295
Hemionitis tomentosa (Lam.) Raddi	AB	TH/LT	SA	27
Pityrogramma calomelanos (L.) Link	AB/ST	TH	NE	189
P. chaerophylla (Desv.) Domin	AB	LT	NE	247
P. trifoliata (L.) R.M.Tryon	ST	TH	NE	191
Pteris denticulata Sw.	AB/ST	TH	NE	42, 208, 1358
P. plumula Desv.	ST	TH	NE	97, 286
P. vittata L.	ST	TR	EX	325
Salviniaceae				
Azolla filiculoides Lam.	AB	AQ	NE	1716
Salvinia auriculata Aubl.	ST	AQ	NE	1387
Tectariaceae				
Tectaria incisa Cav.	AB	TH	NE	39
Thelypteridaceae				
Macrothelypteris torresiana (Gaudich.) Ching	AB/ST	TH	EX	38, 275
Thelypteris amambayensis (Christ.) Ponce	ST	TH	BR	287, 326
T. conspersa (Schrad.) A.R.Sm.	ST	TH	NE	207, 211, 393
T. dentata (Forssk.) E.P.St.John	AB/ST	TH	EX	50, 188, 281
T. grandis var. *kunzeana* (Hook.) A.R.Sm.	ST	TH	SA	284
T. hispidula (Decne.) C.F.Reed	ST	TH	NE	214, 417
T. interrupta (Willd.) K.Iwats.	ST	TH	PA	191
T. lugubris (Mett.) R.M.Tryon & A.F.Tryon	AB/ST	TH	SA	293, 297, 332
T. opposita (Vahl) Ching	ST	TH	NE	277
T. mosenii (C.Chr.) C.F.Reed	ST	TH	SA	292, 298, 299
T. patens (Sw.) Small	ST	TH	NE	340
T. rivularioides (Fée) Abbiatti	ST	TH	SA	278
T. salzmannii (Fée) C.V.Morton	ST	TH	SA	283
T. scabra Lellinger	AB	TH	SA	257, 1355
T. serrata (Cav.) Alston	ST	TH	SA	206

*According to Paciencia (2008).

availability (e.g.,, Windisch 1992), it is expected that Santo Antonio is more favorable for most species, resulting in higher diversity despite the small area. Other studies (e.g., Nóbrega and Prado 2008; Salino and Joly 2001) have also shown a greater richness of ferns and lycophytes in swampy areas, as shown in Table 2.

Our results are in accordance with Tryon and Tryon (1982) who indicated that the three most species-rich families in this study are also the most biodiverse ones of the Neotropical region. The number of species found in this study was slightly higher than reported by Nobrega and Prado (2008) for the forest remant of the Municipal Botanical Garden of Bauru, where they found 54 species. Colli et al. (2004, 2007) reported 34 species for Vassununga State Park and 39 for the Águas da Prata State Reserve. However, the studies by Salino (1996) for the Serra do Cuscuzeiro and by Salino and Joly (2001) for three areas in the Jacaré Pepira River basin showed a much larger number of species for forest remnants in the interior of São Paulo, with 113 and 90 species,

Table 2. List of some studies carried in interior of São Paulo state with indication of phytophysionomies, size of areas and total species. Vegetation (phytophysionomy) – SFR: semideciduous forest; RF: riparian forest; SW: swamp forest; SN: savanna.

Reference	Municipality	Sampled area (ha)	Vegetation	Total Species
Present study	Jaú	RPPN Amadeu Botelho (180) Source of the Santo Antônio Stream (20)	SFR, FR SW, SFR	70
Nóbrega and Prado (2008)	Bauru	Municipal Botanical Garden (321.71)	SN, RF, SW, SFR	54
Colli et al. (2004)	Santa Rita do Passa Quatro	Parque Estadual de Vassununga: Area Capetinga Leste (191) Area Capetinga Oeste (339.8)	 RF, SFR RF, SFR	34
Colli et al. (2007)	Águas da Prata	Reserva Estadual de Águas da Prata (48.4)	SFR	39
Salino and Joly (2001)	Brotas/Itirapina	Viveiro Municipal de Brotas (unknown) Santa Elisa farm (42) Serra de Itaqueri (unknown)	SW SFR SFR	90
Salino (1996)	Analândia	Serra do Cuscuzeiro (unknown)	SFR, SN	113

respectively (Table 2). An explanation for the higher number of species found in these studies may be related with good condition of preservation of the sampling areas. In addition, some of these areas are mountainous, and according to Moran (2008), this type of relief may provide a large amount of micro-environments that enable the occurrence of more species.

The small number of lycophytes in the study areas are in agreement with other studies carried in interior of São Paulo state (Salino 1996; Salino and Joly 2001; Nóbrega and Prado 2008). The distribution of these plants is apparently concentrated in the Dense Rain Forests (Hirai and Prado 2000; Hirai 2015; Øllgaard and Windisch 2014; Windisch et al. 2015). Mountainous regions exhibit higher diversity than areas with flat relief, at least for some genera (Øllgaard and Windisch 1997), as seen to ferns (Moran 1995), and could be an explanation to the lower diversity of lycophytes in the interior of São Paulo state.

As shown in several studies in the interior of Sao Paulo state, the low numbers of epiphytic species here is contrast to the higher diversity in coastal areas of the state (Nobrega and Prado 2008; Colli et al. 2004, 2007; Salino 1996; Salino and Joly 2001). According to Souza et al. (2012), semideciduous forest areas are less favorable to the occurrence of epiphyte species. This may be related to marked seasonality that does not impede the settlement and development of the most drought-adapted species.

Despite the geographical distribution of species, a similar profile was found by Nóbrega and Prado (2008) for Bauru, also located in the interior of São Paulo state. The exotic species [i.e., *Deparia petersenii* (Kunze) M.Kato, *Macrothelypteris torresiana* (Gaudich.) Ching, *Pteris vittata* L. and *Thelypteris dentata* (Forssk.) E.P.St.John] could be associated with anthropic areas, as suggested by Salino and Almeida (2008) who found these same species in Jacupiranga State Park. Moreover, these species currently are considered sub-spontaneous or naturalized (Mynssen 2015; Prado 2015; Salino and Almeida 2015) and occur in various types of vegetation throughout Brazil (Athayde-Filho et al. 2001; Michelon and Labiak 2013; Nóbrega and Prado 2008; Salino 1996; Salino and Joly 2001; Souza et al. 2012).

Therefore, given the current knowledge of the native vegetation of the city of Jaú, the data obtained in this study may be useful towards the protection and preservation of these two remnant forests. These remnants, with different vegetation types, are extremely important because they probably represent the last suitable habitat in the municipality for some species of a distinct flora of ferns and lycophytes .

ACKNOWLEDGEMENTS

We thank the followings plant taxonomists for the assistance in identifications: Dr. Alexandre Salino (Thelypteridaceae), Claudine Mynssen (Athyriaceae) and Lana da Silva Sylvestre (Aspleniaceae). We also thank the Copy Editor for help with the text.

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Author contributions: FM collected the data; FM and FN identified the species, wrote the text, and made the analysis.

Received: 17 January 2014
Accepted: 1 November 2015
Academic editor: Mateus Paciencia